Delta or Estuary: That is the question – The role of ichnology in the interpretation of shallow marine systems, an example from the Clearwater Formation, Cold Lake, Alberta

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Ichnology has increasingly become a necessary 'tool' in any geologist's back pocket when it comes to the interpretation of complex geological systems, and has become somewhat of an art form for those of us who call ourselves ichnologists. Ichnological characteristics can be very useful in facies determination as they document local and regional temporal changes, sedimentary dynamics, and can aid in the reconstruction of individual paleoecological systems (Pemberton and MacEachern, 2006). This is especially true when addressing shallow marine systems where basin dynamics and environments can change very quickly vertically and laterally.

The Clearwater Formation is the primary host to the second largest oil sands deposit in Canada, which is being produced by a number of companies using in-situ cyclic steam injection methods (McCrimmon and Arnott, 2002). There are few detailed papers on the sedimentology, mineralogy and diagenesis of the Clearwater Formation, and to summarize, the strata within the Clearwater Formation is comprised of marginal marine (deltaic/estuarine) and/or marine sediments (shoreface to offshore) (Harrison et.al., 1981; Putnam and Pedaskalny, 1983; Hutcheon et. al., 1989; Beckie and McIntosh, 1989; McCrimmon and Arnott, 2002; Feldman et.al., 2008). The problem is: which is it? Where does it change from marginal marine to marine? Does it change? Is it a delta or an estuary? All of these questions have implications in the continued development and exploratory targets in the Clearwater Formation. For example, tracking sand bodies will depend on whether you are mapping a retrogradational estuarine package within an incised valley complex vs. a laterally extensive, progradational deltaic package. This is where a detailed ichnological analysis can prove helpful.

Within the study area, a re-evaluation of the Clearwater Formation revealed that it was deposited primarily in a tidally dominated deltaic environment. Recognition of the tide-dominated deltaic strata was three-fold:

1. Abundance of tidally influenced structures, i.e. oppositely dipping ripple laminations, abundant mud intraclasts, mud drapes, and heterolithic bedding.
2. Mapping of individual facies associations allowed for the recognition of a progradational stacking pattern, indicating either a deltaic package or a bay-head delta sub-environment in an estuarine valley fill.
3. An ichnological analysis allowed for differentiating between true deltaic and bay-head delta environments (Figure 1).

The trace-fossil suites developed in either a delta or bay-head delta typically show low diversities and low to moderate abundance of ichnofauna reflecting an impoverished *Cruizana* ichnofacies. However, ichnodiversity

levels within the Clearwater sediments are higher than that of a bay-head delta, which usually experiences strong salinity dilution. The common appearance of a range of fully marine traces such as *Scolicia*, *Siphonichnus* and *Rhizocorallium*, and larger, more robust traces support deposition in a deltaic system rather than a bay-head delta of a transgressive estuarine system.

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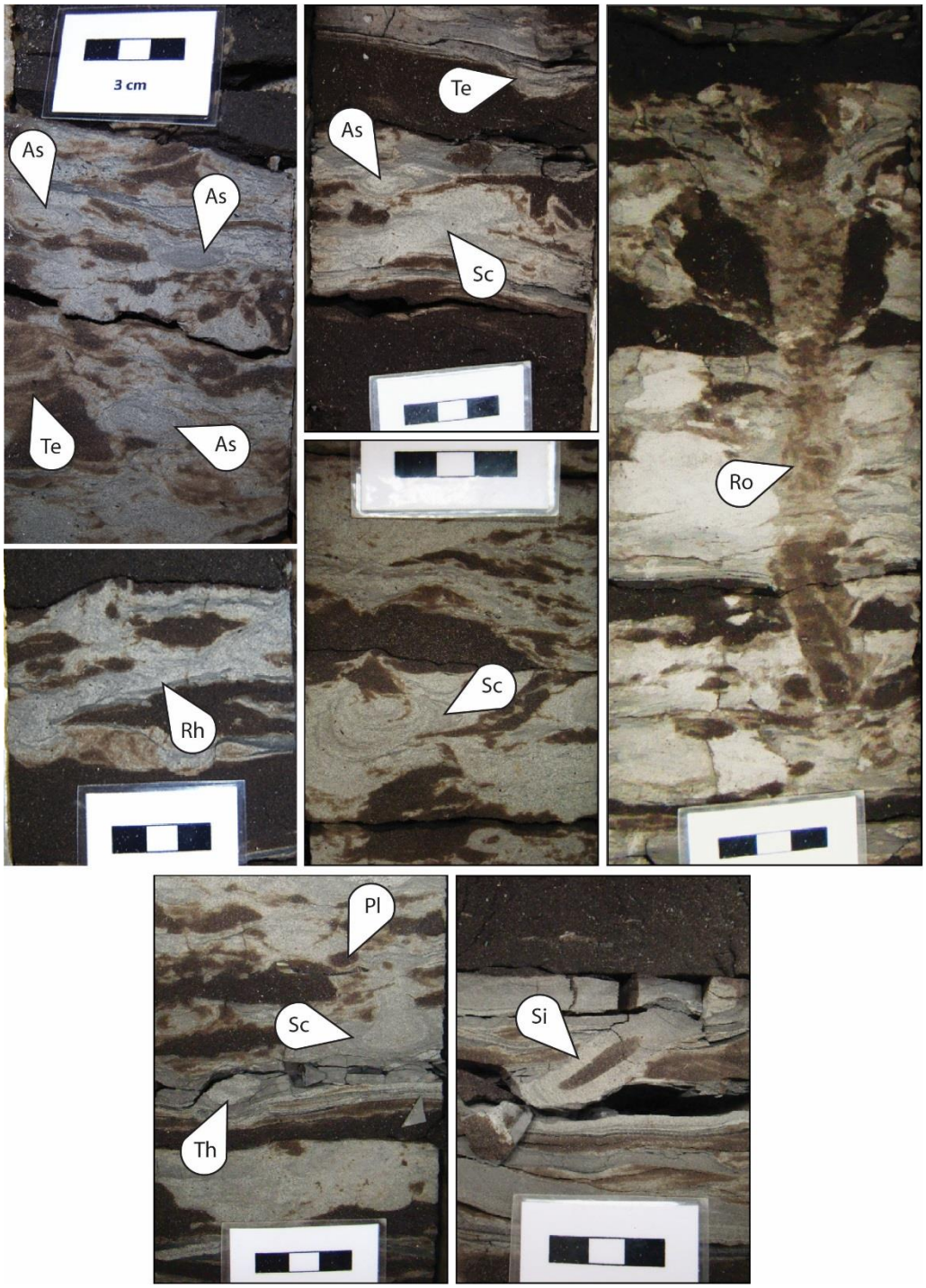

Figure 1: Examples of fully marine trace fossils found in the heterolithic strata of the delta front/prodelta environments in the Clearwater Formation. As – Asterosoma; Te – Teichichnus; Sc – Scolicia; Ro – Rosselia; Rh – Rhizocorallium; Pl – Planolites; Th – Thalassinoides; Si - Siphonichnus